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(56) Documents Cited
GB 2318418 A EP 0735250 A EP 0733786 A
EP 0690213 A

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ONLINE: EPODOC, JAPIO, WPI

(54) Abstract Title

Monitoring of a NOx storage catalyst during operation of an internal combustion engine

(57) A catalytic converter which is capable of storing nitrogen oxides, and which is located in internal combustion engine exhaust gas with a gas sensor downstream of the converter, is monitored. The exhaust gas is influenced in a manner which increases components which have a reducing effect, and the time delay from the commencement of the influence to a change in the sensor signal is monitored as a measure of the NOx storage capacity of the catalytic converter. The influencing may be by changing the exhaust gas mixture from lean to rich, or may involve addition of a reducing agent. An exhaust gas sensor upstream of the catalytic converter may detect the commencement of the influence, and, when reducing agent is added, the amount added may be determined from the delay. The sensors may detect oxygen.

Fig. 2a

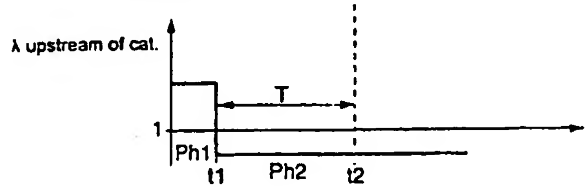

Fig. 2b

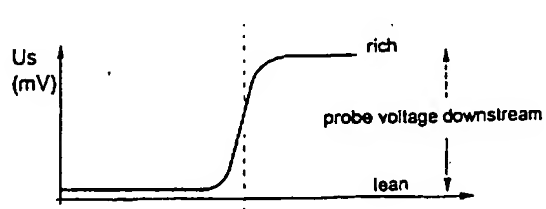

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Fig. 1

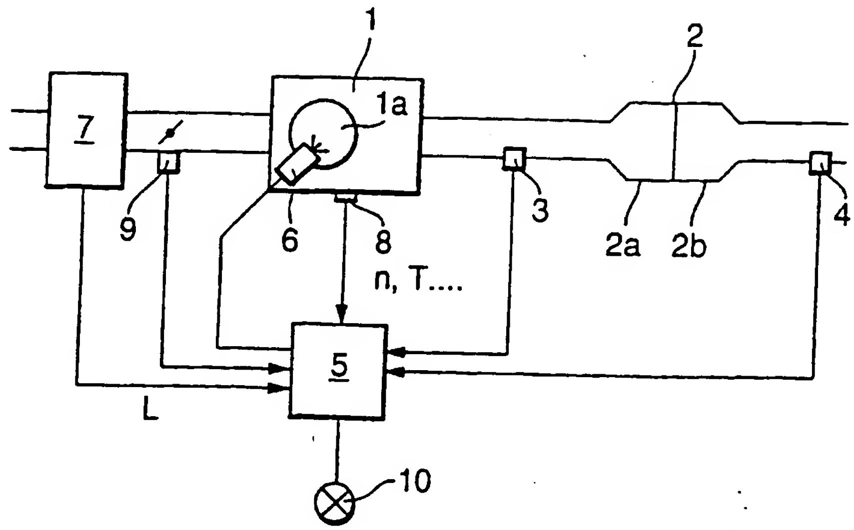


Fig. 2a

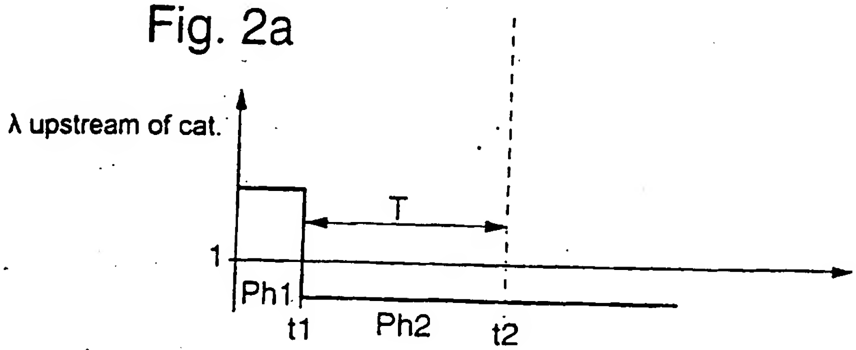


Fig. 2b

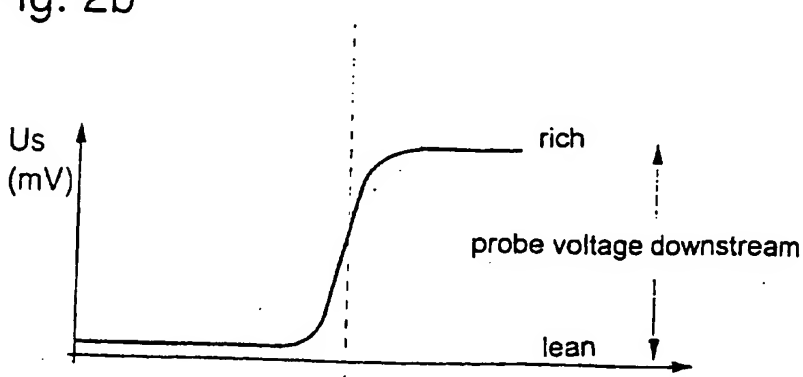


Fig. 3

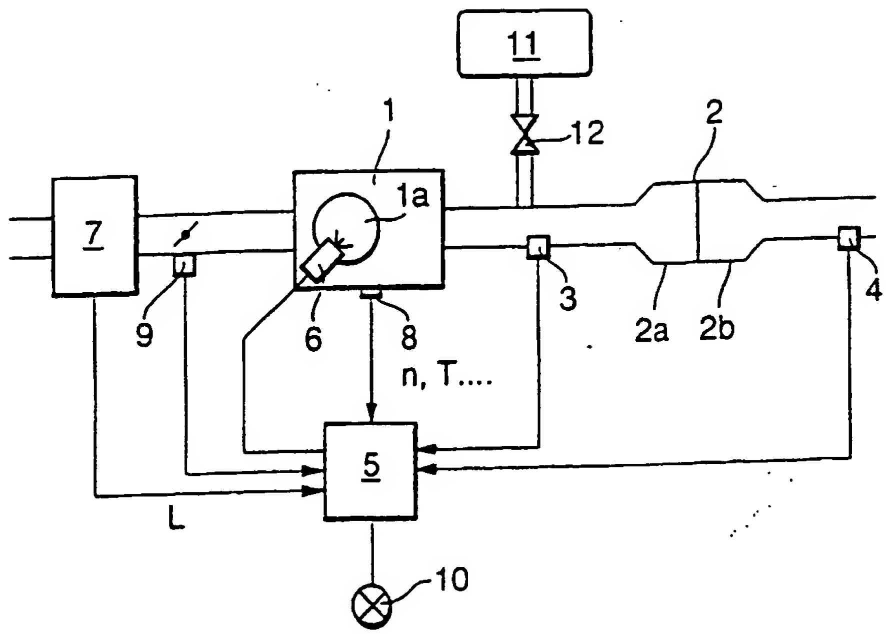


Fig. 4a

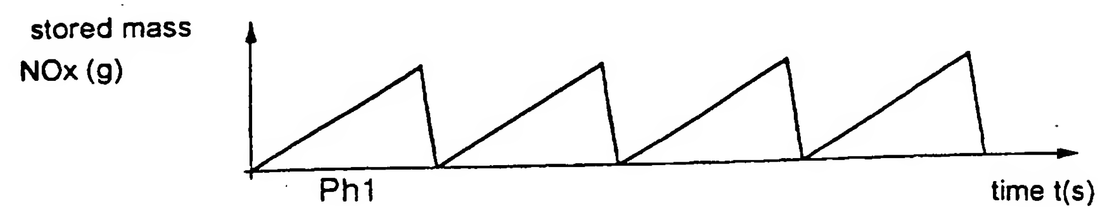


Fig. 4b

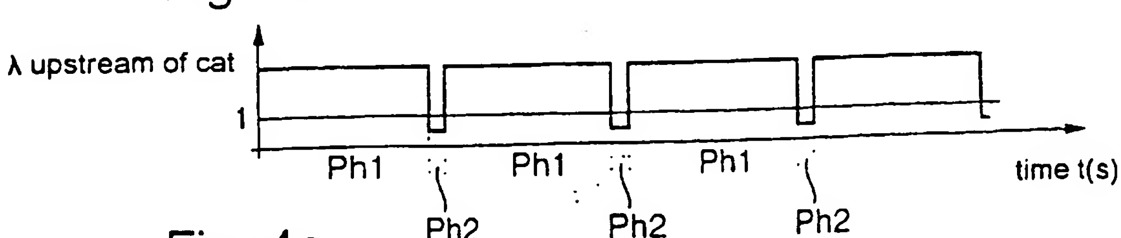


Fig. 4c

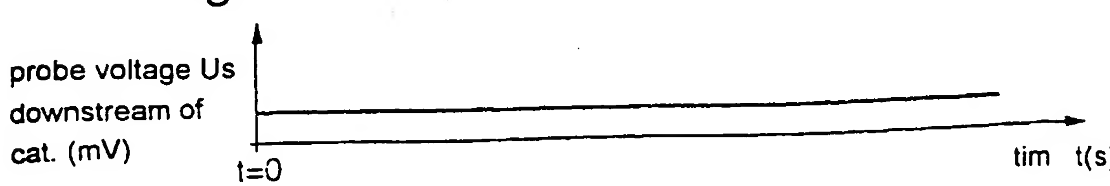


Fig. 5a

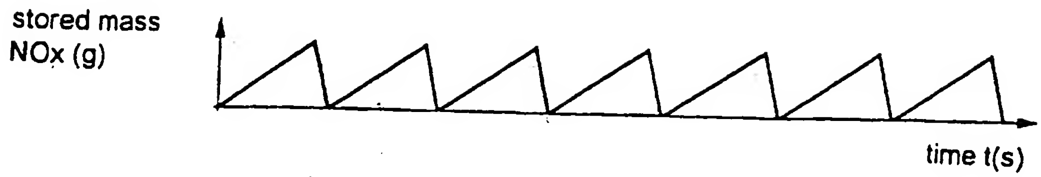


Fig. 5b

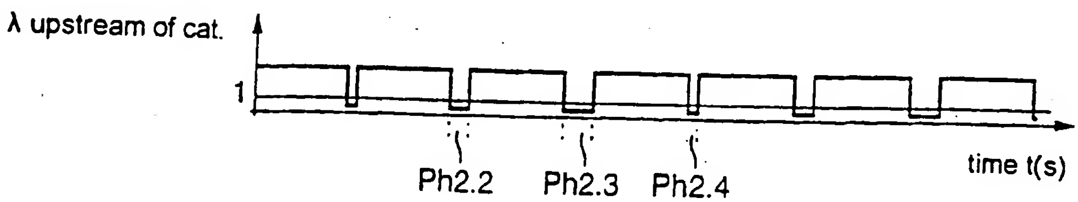
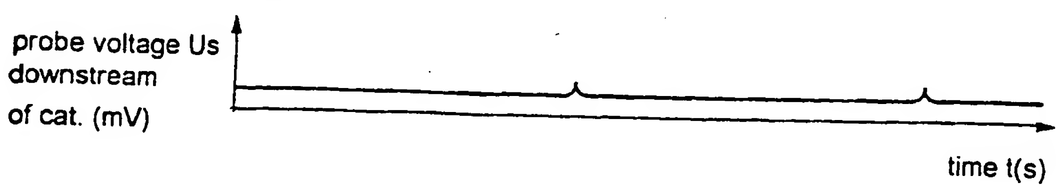


Fig. 5c



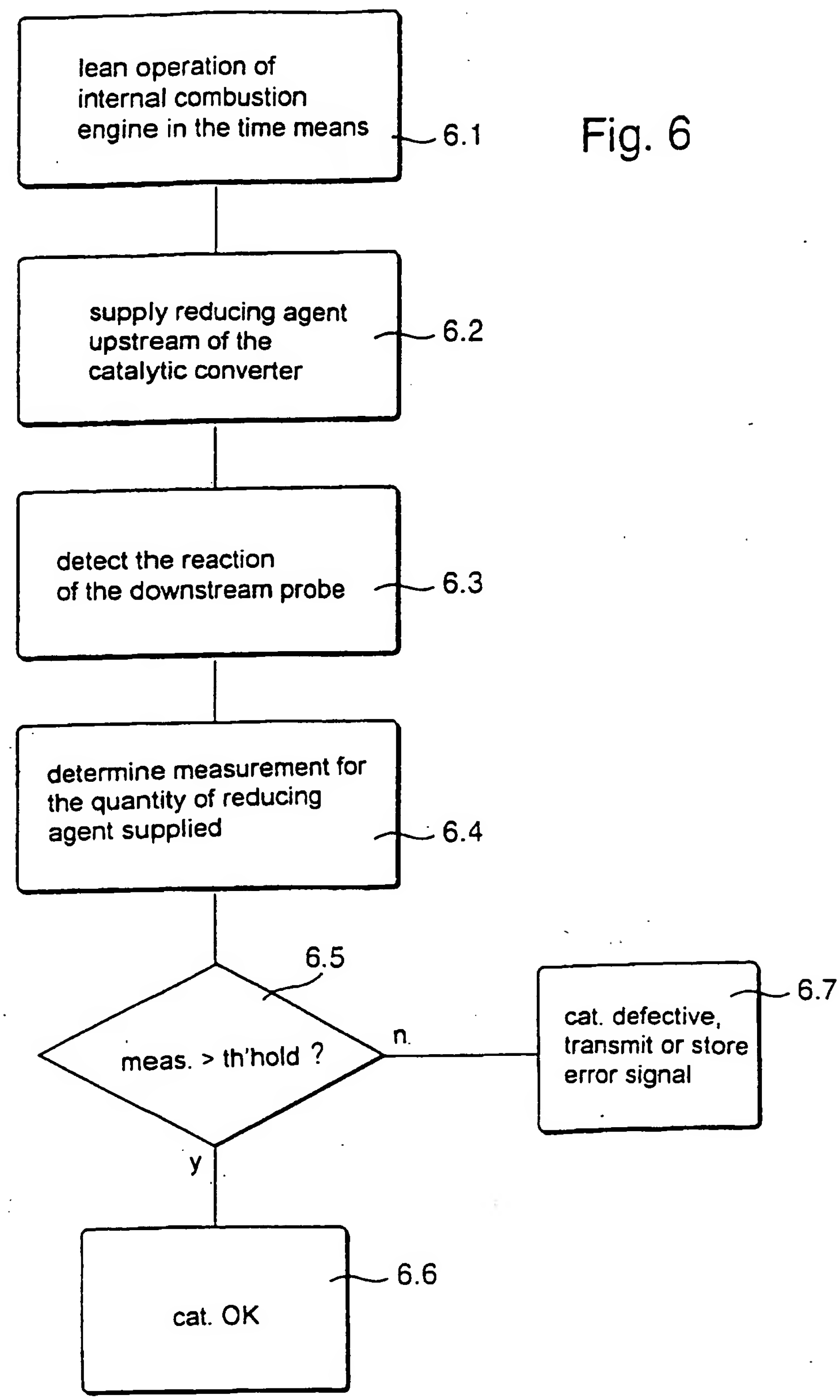

lean operation of internal combustion engine in the time means
6.1
supply reducing agent upstream of the catalytic converter
6.2
detect the reaction of the downstream probe
6.3
determine measurement for the quantity of reducing agent supplied
6.4
6.5
meas. > th'hold ?
n.
y
cat. defective, transmit or store error signal
6.7
cat. OK
6.6

Fig. 6

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DESCRIPTION

MONITORING OF AN NOx-STORAGE CATALYST DURING THE OPERATION OF INTERNAL COMBUSTION ENGINES

The invention relates to the monitoring of catalytic converters, which are used for the purpose of converting pollutants in the exhaust gas of internal combustion engines. In particular, the invention relates to the monitoring of an NOx-storage catalyst during the operation of an internal combustion engine.

In an operating range of the combustion of lean fuel/air mixtures (lambda > 1) the three-way catalytic converter no longer meets the requirements of nitrogen oxide conversion. In this case, NOx-storage catalysts are used, which store the nitrogen oxides emitted during the lean engine operation. When operating the engine in the rich range (lambda < 1), stored nitrates are released and reduced to form nitrogen.

The use of NOx-storage catalysts in this context is known, for example, from EP 560 991 B1.

Legislative requirements provide for an 'On Board' monitoring of motor vehicle components which are relevant to the emission of pollutants, such as catalytic converters. In this context, it is known e.g from DE 24 44 344 to use the signals from an oxygen-sensitive exhaust gas probe, which is disposed upstream and downstream of the catalytic

converter, for the purpose of assessing a three-way catalytic converter. The known method is based upon the capability of a catalytic converter, which can function in three ways, to store oxygen. DE 24 44 334 discloses in this context a change in the fuel/air mixture composition from lambda = 0.95 (rich, fuel-rich mixture, lack of oxygen) to lambda = 1.05 (lean, low fuel mixture, excess quantity of oxygen). The exhaust gas sensor, which is disposed upstream of the catalytic converter, reacts thereto virtually without any delay. Owing to the lack of oxygen, prevailing at lambda = 0.95, in the exhaust gas the oxygen storage areas of the catalytic converter are not occupied initially. After changing over to an excess quantity of oxygen upstream of the catalytic converter, the oxygen storage areas are occupied in a successive manner. Therefore, a lack of oxygen continues to prevail downstream of the catalytic converter after the change-over control procedure. After a period of time, which is dependent upon the capability of the catalytic converter to store oxygen, an excess quantity of oxygen also occurs downstream of the catalytic converter and triggers a change in the signal of the downstream exhaust gas sensor. The time delay, i.e the phase-shift between the reactions of the two exhaust gas sensors decreases as the capability of the catalytic converter to store oxygen decreases, and can therefore be used diagnostically for the purpose of assessing the capability of the catalytic converter to store oxygen.

It is not readily possible to apply this known method to a catalytic

converter, which in addition to the capability to store oxygen, also has the capability to store nitrogen oxides. Conventionally, catalytic converters of this type can still store nitrogen oxides, if their capability to store oxygen is already exhausted and if an exhaust gas sensor, which is disposed downstream of the catalytic converter, indicates an excess quantity of oxygen. Therefore, the time delay between the reactions of the two exhaust gas sensors after a change-over control procedure from a rich to a lean mixture does not provide any statement, in the case of NOx-storage catalysts, regarding their capability to store NOx.

It is a feature of the present invention to provide a method and a device for the purpose of assessing the capability of an NOx-storage catalyst to store NOx, which can be produced if possible with components, which are already provided in modern motor vehicles, and in each case with an oxygen-sensitive exhaust gas sensor upstream and downstream of the catalytic converter.

In accordance with a first aspect of the present invention, there is provided a method for the purpose of monitoring a catalytic converter in the exhaust gas of internal combustion engines having an exhaust gas sensor downstream of the catalytic converter, in which method a change in the signal of the exhaust gas sensor is triggered by influencing the exhaust gas upstream of the catalytic converter and wherein the time delay between the commencement of the influence and the change in the signal is evaluated for diagnostic purposes, wherein the method is

used in the case of a catalytic converter, which is capable of storing nitrogen oxides, and the exhaust gas is influenced in association with an increase in exhaust gas components which have a reducing effect.

In accordance with a second aspect of the present invention, there is provided a monitoring device for a catalytic converter in the exhaust gas of internal combustion engines and an exhaust gas sensor downstream of the catalytic converter, means for the purpose of influencing the exhaust gas upstream of the catalytic converter in order to trigger a change in the signal of the exhaust gas sensor, means for the purpose of detecting and for evaluating the time delay between the commencement of the period of influence and the change in the signal for diagnostic purposes, the device being adapted for use for diagnostic purposes of catalytic converters capable of storing nitrogen oxides, wherein the exhaust gas is influenced in association with an increase in exhaust gas components which have a reducing effect.

The invention also provides a method for the purpose of monitoring a catalytic converter, which is capable of storing nitrogen oxides, in the exhaust gas of internal combustion engines having an exhaust gas sensor downstream of the catalytic converter, in which method a change in the signal of the exhaust gas sensor is triggered by the supply of reducing agent upstream of the catalytic converter and wherein the supplied reducing agent quantity, which triggers a change in the signal, is determined and valuated for diagnostic purposes.

The invention is based upon the fact that a lack of oxygen in the exhaust gas downstream of the catalytic converter only occurs if both the oxygen and the nitrogen oxide storage areas in the NOx-storage catalyst are empty. For example, if the catalytic converter is initially filled with oxygen and nitrogen oxides by virtue of an operation of the internal combustion engine having a lean mixture and if then for the purpose of regenerating the catalytic converter hydrocarbons (HC) and carbon monoxide (CO) are produced in the exhaust gas by virtue of a rich mixture adjustment, the following processes take place: the hydrocarbons and the carbon monoxide reduce the stored nitrogen oxides. The oxygen which is bonded and stored in the form of nitrogen oxides is released together with the remaining oxygen stored in the catalytic converter, so that initially the excess quantity of oxygen is maintained downstream of the catalytic converter.

The exhaust gas sensor, which is disposed downstream of the catalytic converter, only reacts to the lack of oxygen upstream of the catalytic converter if both the oxygen storage areas and the nitrogen oxide storage areas of the catalytic converter are empty. The time delay between the exhaust gas being influenced upstream of the catalytic converter by virtue of the introduction of reducing agents and the reaction of the downstream exhaust gas probe therefore depends upon the capability to store NOx and therefore can be used to assess the capability of the catalytic converter to store NOx.

A conv ntional, oxygen-sensitive lambda probe or for example an HC-sensor can be taken into consideration as a sensor which is disposed downstream of the catalytic converter.

The invention is not limited to a rich control of the engine for the purpose of providing HC and CO in the exhaust gas as a reducing agent. The reducing agent can also be metered in a controlled manner from other sources, for example as carbamide from a storage tank.

The invention is described further hereinafter, by way of example only, with reference to the accompanying drawings, in which:-

Figure 1 shows the technical environment, in which the invention demonstrates its effect,

Figure 2 illustrates the invention by reference to signal graphs,

Figure 3 illustrates a further exemplified embodiment of a device, which is suitable for implementing the invention,

Figures 4 and 5

illustrate by reference to signal graphs the invention in conjunction with a control or regulation of the fuel metering of an internal combustion engine having an NOx-storage catalyst, and

Figure 6 shows a flow diagram as an exemplified embodiment of the invention.

Figure 1 shows in detail an internal combustion engine 1 having a catalytic converter 2, exhaust gas probes 3 and 4, a control device 5, a fuel metering means 6 and different sensors 7, 8, 9 for load L and rotational speed n and where appropriate further operating parameters of the internal combustion engine such as temperatures, throttle valve position etc.. The catalytic converter comprises a first part 2a and a second part 2b. Part 2a represents the NOx-storage catalyst. Part 2b represents an integrated or downstream-connected oxygen storage device.

From the said input signals and, where appropriate, further input signals, the control device forms inter alia fuel metering signals by means of which the fuel metering means 6 is controlled. The fuel metering means 6 can be formed both for a so-called intake pipe injection procedure and for a direct petrol injection procedure into the combustion chambers 1a of the individual cylinders. The mixture composition can be varied by way of a change in the injection pulse widths, by means of which the fuel metering signal is controlled. The core of the method in accordance with the invention relates primarily in this environment to the control device 5, the exhaust gas probe 4, which is disposed downstream of the catalytic converter, and the means 10 for

indicating and/or storing information regarding the storage capability. The device in accordance with the invention is produced therefrom by virtue of the features of the device claims.

Figure 2 illustrates in 2a the change in the mixture composition upstream of the catalytic converter in conjunction with the signal US of the downstream exhaust gas probe 4 (Figure 2b) in the case of one exemplified embodiment of the invention.

In a first phase Ph1 the engine is operated at lambda > 1, i.e with an excess quantity of air. The low signal level of the downstream probe in Figure 2b indicates that an excess quantity of air or oxygen also prevails downstream of the catalytic converter. At time t1 the mixture composition is changed-over from lambda > 1 to lambda < 1, i.e a lack of oxygen. At time t2 the downstream sensor 4 reacts to the lack of oxygen with an increase in its signal from a low to a high level. For the reasons described above, the duration T = value(t2-t1) is a measurement for the sum of the capability of the catalytic converter system to store NOx and oxygen. In other words: the time T is a variable which is suitable for quantitative assessment. As is evident in Figure 2b, the time t2 can be predetermined for example by virtue of the signal from the downstream probe exceeding the threshold value.

The time t1 can be detected directly in the control device. In the event of a sudden change-over of lambda, t1 is the time at which the injection pulse widths are increased. In this case, t1 is still encumbered

with the indeterminacy in the gas running time between the commencement of the injection procedure and the time at which the combustion products reach the catalytic converter. However, this time is short with respect to the time T and can therefore be neglected in a first approximation. If a higher degree of accuracy in the determination of the time t1 is desired, the time of the signal level change of the upstream exhaust gas probe 3 can be used. The illustrated change in the mixture composition results in the fact that the internal combustion engine emits hydrocarbons and carbon monoxide as a reducing agent. As an alternative to the emission of exhaust gas components, which have a reducing effect, the reducing agent can also be supplied from a storage tank 11 by way of a valve 12, which is controlled by the control device 5, to the exhaust gas upstream of the catalytic converter. The engine can then be operated in a continuous manner with a lean mixture. A corresponding modification in the structure of Figure 1 is illustrated in Figure 3.

With reference to signal graphs, Figures 4 and 5 illustrate how the invention can be incorporated into a control and/or regulating method of the fuel metering procedure of an internal combustion engine in conjunction with an NOx-storage catalyst.

The internal combustion engine is operated in an alternate manner in first phases Ph1 with a mixture, which comprises a lower quantity of fuel (lean) than the stoichiom tric mixture composition

(lambda = 1), and is operated in second phases Ph2 with a mixture, which comprises a greater quantity of fuel (rich). In the first phases the NOx-catalyst stores the NOx-emissions of the engine. In the second phases a defined enrichment regenerates the storage catalyst. The regeneration is achieved by way of a reduction in the stored nitrates to form nitrogen (N_2). In order to achieve high storage and conversion rates in the NOx-storage catalyst, the storage device 2a must be virtually completely emptied and thus sufficient reducing agent must be supplied.

Figure 4 illustrates the phase change in conjunction with an illustration of the stored NOx quantity (Figure 4a), the associated fuel/air ratio lambda, as detected by the exhaust gas probe 3 (Figure 4b) which is disposed upstream of the catalytic converter, and the signal behaviour of the exhaust gas probe 4 (Figure 4c), which is disposed downstream of the catalytic converter, for the ideal case to be sought in each case of completely filling and emptying the NOx-storage catalyst.

At time t=0 the NOx-storage catalyst is empty. In the following first phase Ph1 the internal combustion engine is operated with a lean mixture (lambda > 1). The nitrogen oxides emitted are stored in the storage catalyst. The first phase (lean phase) is terminated ideally when the storage catalyst 2a is full. The first phase is followed by a second phase Ph2, in which the storage catalyst is regenerated. In this xemplified embodim nt the r g neration is achieved with the aid of a

rich engine operation in the phase Ph2. The internal combustion engine, which operates with a richer fuel mixture, emits non-combusted HC and CO as a reducing agent. Under the influence of the catalytic converter the reducing agent reacts with the stored nitrogen oxides to produce water, CO_2 and N_2, which are transported further with the exhaust gas. As a result, the storage device is then ready to receive nitrogen oxides once again, i.e is regenerated. Between the phases Ph1 and Ph2 the control device 5 performs a continuous change-over procedure.

In an ideal case, the regeneration (phase 2) is achieved until the storage catalyst 2a is completely emptied and the regeneration procedure is terminated, before an excess quantity of reducing agent occurs downstream of the catalytic converter. The occurrence of an excess quantity of reducing agent is associated with a lack of oxygen and can therefore be detected by means of an oxygen-sensitive exhaust gas sensor 4. Alternatively, it is also possible for example for excess quantities of hydrocarbons to be detected directly by means of an HC-sensor instead of or supplementary to the oxygen-sensitive exhaust gas sensor 4. As shown in Figure 4a, the storage catalyst is in each case completely empty at the end of a rich phase Ph2 and as shown in Figure 4c the signal behaviour of the exhaust gas sensor 4, which is disposed downstream of the catalytic converter, does not change. The illustrated low level of th sensor signal represents an excess quantity of

oxygen and thus the consumption-optimised lean operation of the internal combustion engine which is predominant in the time means.

Since it is not possible to calculate precisely the required reducing agent quantity in the engine operation, the catalytic converter 2 is designed in an advantageous manner as an NOx-storage catalyst having an integrated capability to store oxygen or is designed as a conventional three-way catalytic converter having an oxygen storage device 2b which serves as a buffer. An unacceptably high supply of the reducing agent CO and HC will react with the oxygen stored in the oxygen storage device 2b. The downstream-connected oxygen storage device is ideally only half-emptied by virtue of an excess quantity of reducing agent. The downstream-connected oxygen storage device permits a certain overdosing of the reducing agent which is advantageous for the purpose of ensuring that the storage catalyst 2a is emptied completely. The intended procedure of half-emptying the oxygen storage device renders it possible to equalize dosing indeterminacy which is unavoidable during actual operation.

Figure 5 illustrates an exemplified embodiment of the invention in association with the illustration of Figure 4.

As is evident in Figure 5b, the internal combustion engine is initially controlled in such a manner that the sensor 4, which is disposed downstream of the catalytic converter, does not change its signal behaviour and remains at a level characteristic of a lean mixture. This

can mean that the length of the rich phases is already ideal, i.e with the exception of dosing indeterminacy, which is buffered by the oxygen storage catalyst 2b, the length corresponds to the requirement, so that the storage catalyst 2a is completely regenerated. However, it is also possible that the length of the rich phases is not sufficient in order to regenerate the storage catalyst completely. Therefore, the length of the rich phases is increased successively to a certain extent as a means of testing. At the end of the third illustrated rich phase Ph2.3 the reducing agent charge into the catalytic converter system 2 exceeds the value, which is predetermined by virtue of the regeneration requirement (2a) plus the buffer variable (2b), with the consequence that downstream of the catalytic converter a lack of oxygen occurs in conjunction with an excess quantity of reducing agent such as CO and HC.

Figure 5c shows the resulting change in the signal behaviour of the exhaust gas sensor 4, which can be detected for example by virtue of a threshold value comparison, as also illustrated in Figure 2b. The length of the rich phase Ph3 is used in accordance with the invention as a measurement for the capability to store NOx.

Therefore, the rich phase Ph2.3 associated with triggering the signal change is too long, in order to be buffered by the catalytic converter system 2, whereas the preceding rich phase Ph2.2 was not yet long enough, in order to trigger a reaction. The actual reducing agent requirement can therefore be eliminated with a fine detail which is

determined by the step width of the successive extensions.

The following rich phases PH2.4 etc. are shortened, wherein the extent of the reduction is dimensioned in such a manner that the storage catalyst 2a is still being completely regenerated, however, approximately only half of the oxygen storage catalyst 2b is emptied. Subsequently, the method is repeated, i.e the length of the rich phases is increased in a successive manner once again. However, it is not compulsory for the extension to be commenced immediately. It is also feasible, to store the value, which has been ascertained as optimum, for the current operating point and to commence a new adaption procedure after a certain time only after predetermined conditions have taken effect.

As an alternative to the successive change in the rich phases, it is also possible to implement a successive increase in the degree of enrichment. Both alternatives can also be combined.

The reducing agent quantity, which is supplied until the reaction of the downstream sensor, depends upon the overall storage capability of the catalytic converter system. In accordance with the invention, in order to assess the storage capability the quantity of the supplied reducing agent is detected. For example, this can be achieved by detecting the regeneration period Ph 2.3 until the emergence of the reducing agent. This period corresponds to the above mentioned time T, which for example by virtue of a threshold comparison can be used for monitoring the catalytic converter. Alternatively, the supplied

reducing agent quantity can be compared to a threshold value. The greater the quantity supplied until the emergence of said reducing agent, the greater is the storage capability of the catalytic converter. When reducing agent is supplied as shown in Figure 3, the quantity can be determined for example from the control signal for the valve 12. In the event of an emission of exhaust gas components, which have a reducing effect, the quantity can be determined for example from the signal of the upstream probe 3 and of the intake air quantity. The intake air quantity reproduces the entire gas flow into the catalytic converter and the exhaust gas sensor signal provides a signal regarding the proportion of reducing agent. The connections between the reducing agent quantity, sensor signal and air quantity can be ascertained for example by tests and stored in a characteristic diagram in the control device 5.

The self-explanatory flow diagram of Figure 6 illustrates this procedure as an exemplified embodiment. The step 6.6 comprises the alternatives explained in the text above: it is possible to take into consideration in particular the reaction time T as a measurement for the supplied reducing agent quantity.

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CLAIMS

1. A method for the purpose of monitoring a catalytic converter in the exhaust gas of internal combustion engines having an exhaust gas sensor downstream of the catalytic converter, in which method a change in the signal of the exhaust gas sensor is triggered by influencing the exhaust gas upstream of the catalytic converter and wherein the time delay between the commencement of the influence and the change in the signal is evaluated for diagnostic purposes, wherein the method is used in the case of a catalytic converter, which is capable of storing nitrogen oxides, and the exhaust gas is influenced in association with an increase in exhaust gas components which have a reducing effect.

2. A method according to claim 1, wherein the change in the signal of the exhaust gas sensor is triggered by influencing the exhaust gas upstream of the catalytic converter by virtue of an increase in the fuel quantity supplied to the internal combustion engine.

3. A method according to claim 1, wherein the change in the signal of the exhaust gas probe is triggered by virtue of the addition of reducing agent to the exhaust gas upstream of the catalytic converter.

4. A method according to claim 1, wherein the commencement of period of influence is detected by virtue of the change in the signal of an exhaust gas sensor which is disposed upstream of the catalytic converter.

5. A method according to claim 1, wherein as the fuel/air ratio is

controlled, the internal combustion engine is operated in an alternate manner in first phases with a mixture, which comprises a lower quantity of fuel than the stoichiometric mixture composition, and is operated in second phases with a mixture, which comprises a greater quantity of fuel, and wherein the period of a second phase is detected which leads to a reaction of the downstream exhaust gas sensor, and wherein this period is evaluated as diagnosis criterion.

6. A monitoring device for a catalytic converter in the exhaust gas of internal combustion engines and an exhaust gas sensor downstream of the catalytic converter, means for the purpose of influencing the exhaust gas upstream of the catalytic converter in order to trigger a change in the signal of the exhaust gas sensor, means for the purpose of detecting and for evaluating the time delay between the commencement of the period of influence and the change in the signal for diagnostic purposes, the device being adapted for use for diagnostic purposes of catalytic converters capable of storing nitrogen oxides, wherein the exhaust gas is influenced in association with an increase in exhaust gas components which have a reducing effect.

7. A device according to claim 6, having an exhaust gas sensor, which is oxygen-sensitive.

8. A device according to claim 6, having a further exhaust gas sensor, which is disposed upstream of the catalytic converter, wherein the time delay is detected as a phase shift between the signal of the

upstream exhaust gas sensor and of the downstream exhaust gas sensor.

9. A device according to claim 6, having means for the purpose of increasing the quantity of fuel supplied to the internal combustion engine, for the purpose of influencing the exhaust gas upstream of the catalytic converter in order to increase the proportion of exhaust gas components which have a reducing effect.

10. A device according to claim 6, having means for the purpose of supplying reducing agent to the exhaust gas upstream of the catalytic converter in order to increase the proportion of exhaust gas components which have a reducing effect.

11. A method for the purpose of monitoring a catalytic converter, which is capable of storing nitrogen oxides, in the exhaust gas of internal combustion engines having an exhaust gas sensor downstream of the catalytic converter, in which method a change in the signal of the exhaust gas sensor is triggered by the supply of reducing agent upstream of the catalytic converter and wherein the supplied reducing agent quantity, which triggers a change in the signal, is determined and evaluated for diagnostic purposes.

12. A method for the purpose of monitoring a catalytic converter in the exhaust gas of an internal combustion engine, substantially as hereinbefore described with reference to the accompanying drawings.

13. A monitoring device of a catalytic converter in the exhaust

gas of an internal combustion engine, substantially as hereinbefore described with reference to the accompanying drawings.

The Patent Office

20

INVESTOR IN PEOPLE

Application No:	GB 9828464.9	**Examiner:**	Dave Mobbs
Claims searched:	1-13	**Date of search:**	24 February 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): G1N NBKT, NBMH.

Int Cl (Ed.6): F01N 7/00.

Other: ONLINE: EPODOC, JAPIO, WPI.

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A, P, X	GB 2,318, 418 A	(Ford Global Technologies Inc.).	X: 6-9
A	EP 0,735,250 A	(Toyota Jidosha Kabushiki Kaisha).	
A	EP 0,733,786 A	(Toyota Jidosha Kabushiki Kaisha).	
A	EP 0,690,213 A	(Toyota Jidosha Kabushiki Kaisha).	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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&	Member of the same patent family		